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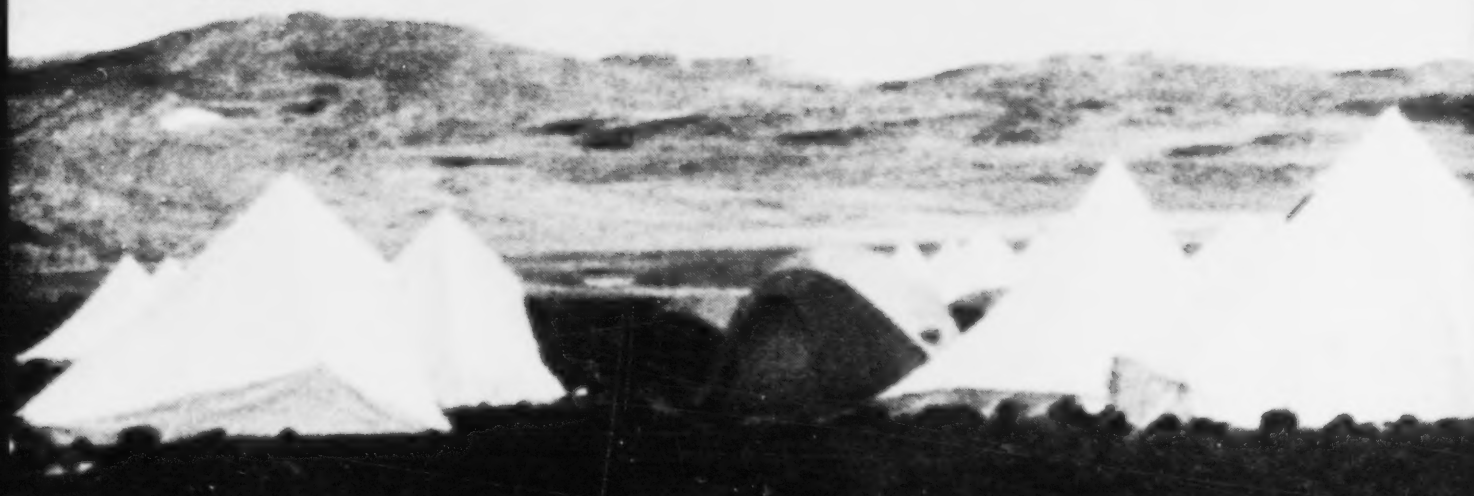

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Preliminary results of the Flin Flon Targeted Geoscience Initiative, Saskatchewan and Manitoba[1]

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Abstract: The objective of the Flin Flon Targeted Geoscience Initiative is to ensure the future of the northern mining community of Flin Flon, Manitoba by working with the local mining and exploration companies to gain a better understanding of the volcanic setting and hydrothermal signatures of the region's volcanogenic massive sulphide deposits. The Geological Survey of Canada–Manitoba–Saskatchewan–Laurentian Univeristy project includes regional-scale and detailed oxygen isotope, mineral-chemical, and sulphide trace-element studies, and a 1:10 000 scale crossborder geological compilation of the Flin Flon Domain. Detailed studies include an alteration study of the Baker–Patton rhyolite complex, and studies of volcanic architecture and hydrothermal evolution of the host stratigraphy to the auriferous Flin Flon–Triple 7–Callinan volcanogenic massive sulphide deposits.

Résumé : L'objectif du projet de Flin Flon de l'Initiative géoscientifique ciblée est d'assurer l'avenir de Flin Flon, collectivité minière du nord du Manitoba, en collaborant avec les sociétés d'exploitation et d'exploration minières locales afin d'approfondir nos connaissances du cadre volcanique et des signatures hydrothermales des gisements de sulfures massifs volcanogènes de la région. Le projet auquel collabore la Commission géologique du Canada, les services géologiques du Manitoba et de la Saskatchewan ainsi que l'Université Laurentienne comprend des études régionales et détaillées sur les isotopes de l'oxygène, la minéralogie et la géochimie, la composition en éléments traces des sulfures, ainsi qu'une compilation géologique transfrontalière du domaine de Flin Flon à l'échelle de 1/10 000. Les études détaillées comprennent une étude de l'altération du complexe rhyolitique de Baker-Patton, ainsi que des études sur la l'organisation des empilements volcaniques et l'évolution hydrothermale des roches encaissantes des gisements de sulfures massifs volcanogènes à minéralisation aurifère de Flin Flon–Triple 7–Callinan.

[1] Contribution to Flin Flon Targeted Geoscience Initiative

INTRODUCTION

The world's Paleoproterozoic volcanic belts contain more massive sulphide deposits per square kilometre than those of any other era (Franklin et al., 1998). Principal among these is the Flin Flon belt of north-central Manitoba and Saskatchewan (Fig. 1). To date, the 26 VMS (volcanogenic massive sulphide) deposits have been developed in the belt containing over 160 Mt worth in excess of 25Cdn billion dollars. This has resulted in prosperity for the towns of Creighton, Flin Flon, and Snow Lake, along with the development of long-term infrastructure for northern Manitoba and Saskatchewan.

With only three operating VMS mines remaining in the Flin Flon belt, there is some concern as to the long-term economic stability of the region. The objectives of the Flin Flon Targeted Geoscience Initiative are therefore to: increase understanding of the volcanic and hydrothermal history of the central Paleoproterozoic Flin Flon volcanic belt; determine how these factors influenced the formation of contained VMS deposits; and assist in the development of exploration strategies to support the discovery of new VMS deposits.

The program involves nine separate, but integrated subprojects within three of the region's major VMS-hosting structural domains. The subprojects include three large-scale studies: delineation of oxygen-isotope patterns for regional-scale VMS-related hydrothermal systems; trace-element research on ores from all known VMS deposits and major sulphide occurrences; and a 1:10 000-scale crossborder geological compilation of the Flin Flon area.

In addition six detailed studies are grouped into four subprojects: an alteration study of the Baker–Patton rhyolite complex; an alteration study of the Bear Lake "volcano"; a combination of detailed and large-scale hanging-wall studies of the Flin Flon VMS horizon; and 1:500-scale mapping and stratigraphic analysis of volcanological, sedimentological, and structural features along the Flin Flon–Triple 7 and Callinan VMS deposits' 'mine horizon'

GEOLOGICAL SETTING

The project area encompasses the 1.92–1.88 Ga Flin Flon arc assemblage, which forms part of a collage of oceanic seafloor and arc terranes comprising the Flin Flon belt (Lucas et al., 1996). The Flin Flon arc assemblage consists mostly of subaqueous basalt and basaltic andesite flow formations that contain discrete occurrences of rhyolite flows and associated volcaniclastic strata. The western part of the arc assemblage is dominated by 1.92 Ga tholeiitic formations, whereas the eastern part is dominated by 1.88 Ga calc-alkalic to shoshonitic volcanic rocks. These arc successions were amalgamated by intra-oceanic accretion (D_1-D_2) between 1.88 Ga and 1.87 Ga. The assembled terranes were then overlain by postaccretion sedimentary and successor arc 1.87–1.84 Ga plutonic rocks. Terminal collision (D_3-D_5) took place between 1.84 Ga and 1.78 Ga (Lucas et al., 1996). The resulting map pattern is characterized by a series of north-northeast-striking faults that divided the Flin Flon arc assemblage into a number of structural domains, each with a distinctive volcanic stratigraphy (Fig. 1). The regional metamorphic grade increases northwards through the Flin Flon arc assemblage from prehnite-pumpellyite through to amphibolite facies, although most rocks have a greenschist mineral assemblage.

The 14 significant VMS deposits within the Flin Flon arc assemblage contain over 120 Mt of massive sulphide mineralization (Fig. 2). They are most common within the primitive tholeiitic arc terranes of the western part of the Flin Flon arc assemblage, but also occur within the more calc-alkalic subaqueous volcanic formations to the east (Syme and Bailes, 1993). Most of the deposits can be classified as mafic-bimodal VMS (Barrie and Hannington, 1999) and are associated with discrete rhyolite flow complexes within the dominantly mafic volcanic packages. This includes the giant 64 Mt Flin Flon deposit, and associated Triple 7 and Callinan deposits. Others, such as West Arm, White Lake, and Cuprus, are hosted within argillite formations that overlie volcanic successions, whereas Flexar, Birch, and Konuto deposits are mafic volcanic hosted with no apparent rhyolite or sediment association. These latter deposits are more akin to ophiolite-hosted VMS deposits.

REGIONAL SUBPROJECTS

Oxygen-isotope mapping of VMS hydrothermal systems (B. Taylor, GSC)

The purpose of this subproject is to generate domain-scale maps showing the variations in oxygen isotopic values for volcanic and subvolcanic units associated with known or potential VMS mineralization. Taylor and South (1985), Cathles (1993), and Taylor (B.E. Taylor, unpub. report, 1997) have demonstrated that oxygen isotopes are a sensitive tool in determining the distribution of volcanic and subvolcanic rocks affected by sub-seafloor hydrothermal alteration. Furthermore, anomalous isotopic values, as defined by variations in $^{18}O/^{16}O$ normalized to modern seawater ($\delta^{18}O$) can assist in determining both the high- and low-temperature parts of the hydrothermal system, which commonly bracket the potential VMS horizon (Fig. 3).

Samples will be collected from the Manitoba Geological Survey (MGS) archives, and from the other ongoing Flin Flon Targeted Geoscience Initiative subprojects to be analyzed at the GSC. From these analyses, maps will be generated at various scales (1:5000–1:10:000) displaying the size and nature of the hydrothermal systems that generated VMS deposits in the Flin Flon, Bear Lake, and Baker–Patton domains (Fig. 1).

Trace-element signatures of Flin Flon VMS deposits (I. Jonasson and D. Ames, GSC)

One of the interesting aspects of current metallogenic studies is the profiling of Canadian VMS deposits through their trace- and rare-earth element signatures of host rocks and ores. These signatures are determined by the nature of the

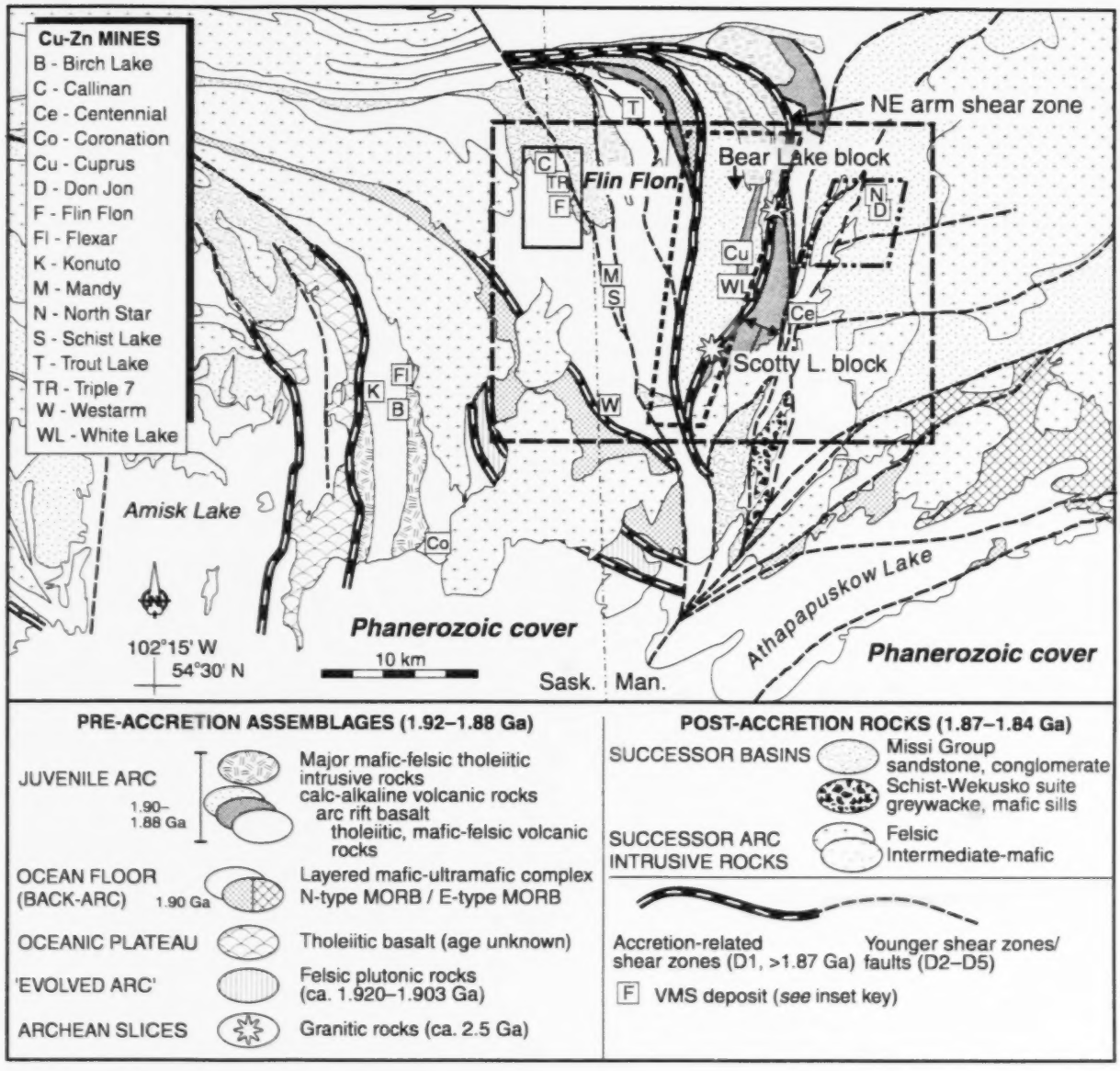

Figure 1. Location diagram of the geology of the Flin Flon volcanic assemblage showing the location of the Flin Flon Targeted Geoscience Initiative subprojects (modified from *Lucas et al., 1996*).

hydrothermal fluid, and the chemistry of the footwall strata, which supply metals and other elements to the hydrothermal fluid. The chemistry of these footwall rocks can be unique to the particular tectonic environment in which the VMS deposits were formed.

The distinctive trace-metal signatures of sulphide ores from VMS deposits may also be used as exploration vectors. Sulphides intercepted during drill programs or prospecting can be analyzed, and their signatures compared to the geochemical archive developed during the Flin Flon Targeted Geoscience Initiative. This can be particularly useful in determining whether a prospect lies along a known VMS-hosting stratigraphic succession, thereby allowing a more accurate assessment of the type of massive sulphide to be expected if drilling is continued.

To date, over 300 samples from 14 deposits and major occurrences have been collected and processed for geochemical analysis. This involves whole-rock ore analysis only, but sulphide separates (pyrite, sphalerite, pyrrhotite, and chalcopyrite) will be available for future analysis. This includes samples from GSC archives, Hudson Bay Exploration and Development Co. Ltd., and those collected during the first

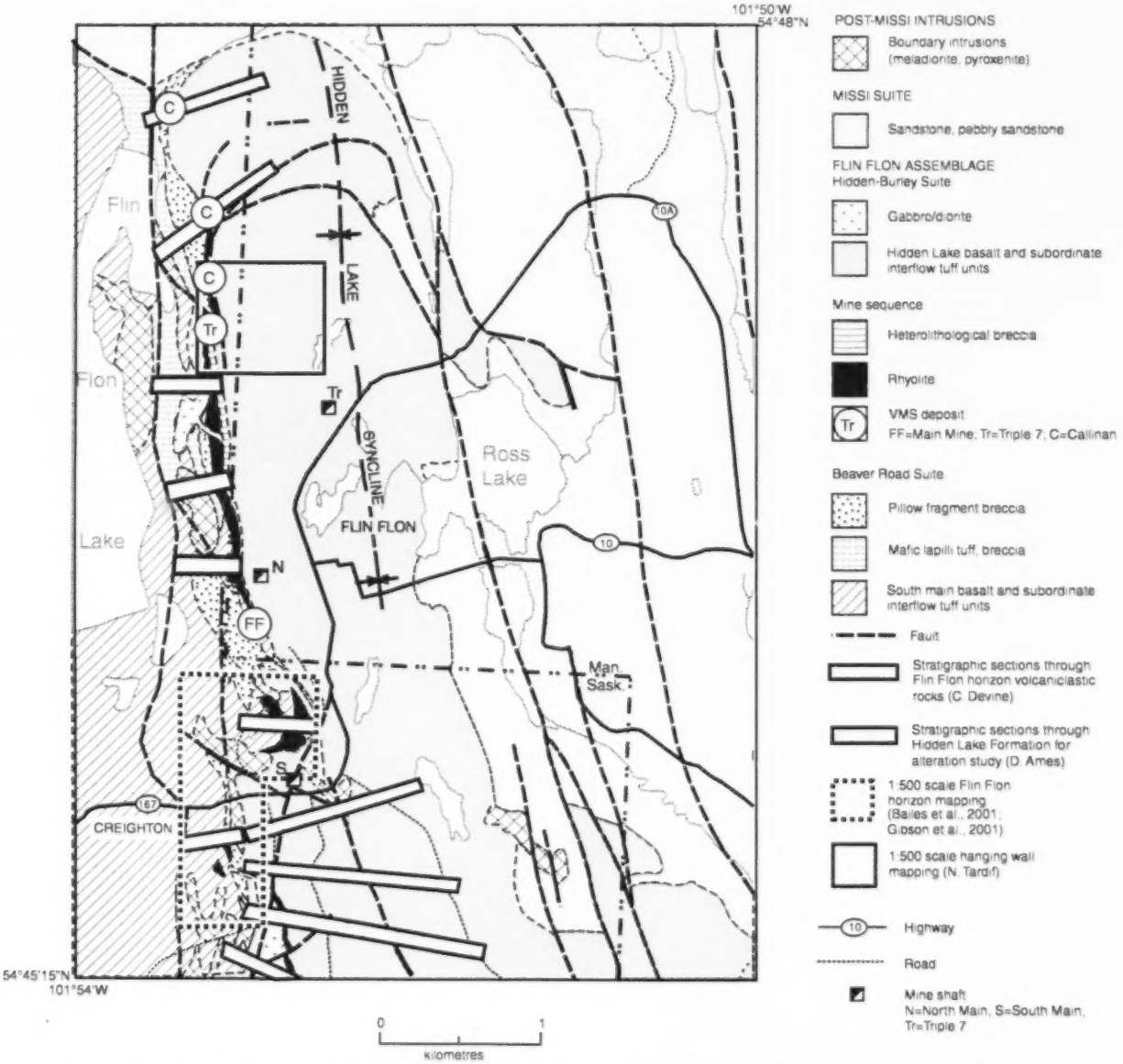

Figure 2. *Detailed geology of the Flin Flon block showing the location of subprojects in the immediate area of the Flin Flon–Triple 7–Callinan mine horizon.*

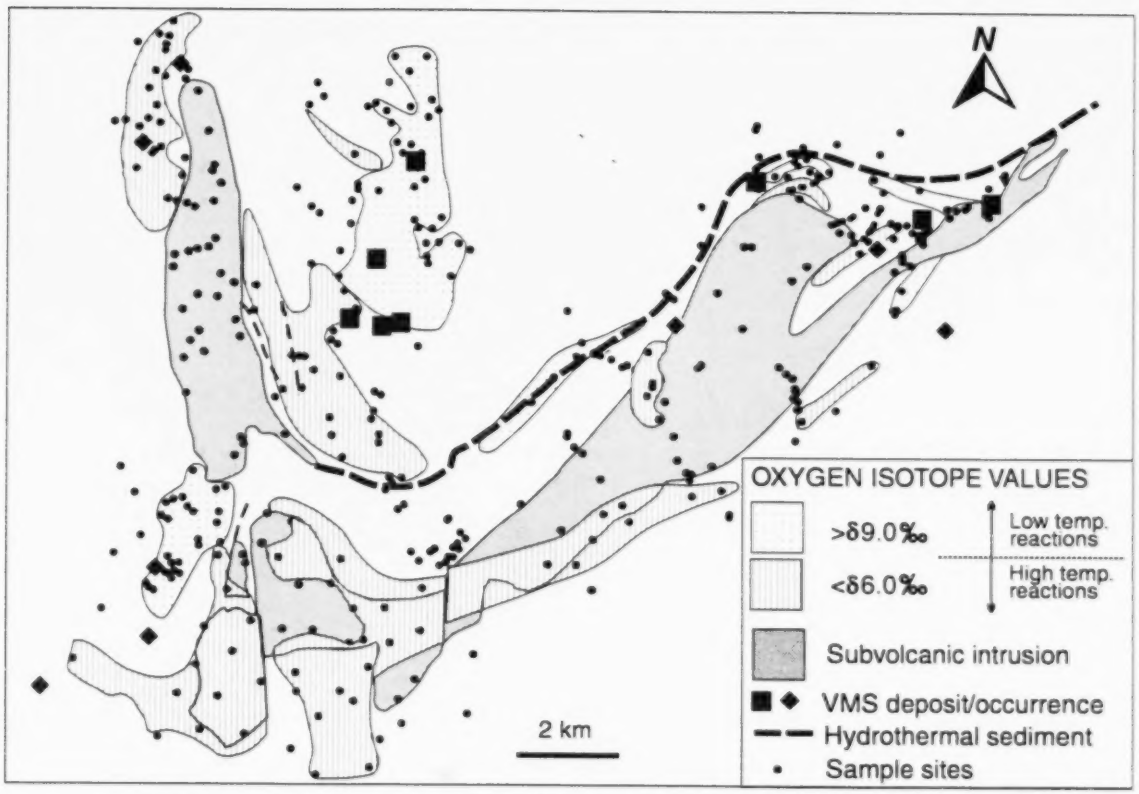

Figure 3. *An example of a regional oxygen isotope survey completed in the Snow Lake VMS camp, eastern Flin Flon belt, during the CAMIRO Project 94E07. The close association of high-temperature reaction zones with two large, subvolcanic tonalite-trondhjemite intrusions suggests that their emplacement triggered and sustained VMS-related activity* (after *B.E. Taylor, unpub. report, 1997, Fig. 2).*

two years of the project. Furthermore, these samples have been slabbed, polished, and photographed. The photographs will be part of a digital datafile from the Flin Flon Targeted Geoscience Initiative, and the slabs will be available for permanent archive and display at a Flin Flon venue (yet to be determined) and will be of great value for exploration and public education in general.

Crossborder geological compilation (A. Bailes (MGS), G. Tourigny (SGS), and H. Gibson (Laurentian University))

The GSC recognized the importance of the Flin Flon region early in the life of the new mining camp by having detailed geological mapping completed in the vicinity of Flon Flon–Creighton by Stockwell (1960) and Heywood (1966). Bailes and Syme (1987) included the Manitoba part of the VMS-hosting Flin Flon arc assemblage in their 1:20 000-scale geological map, whereas the Saskatchewan side of the Flin Flon area was remapped by Thomas (1992, 1994). During the last 15 years Hudson's Bay Exploration and Development Co. Ltd. completed a detailed 1:5 000-scale map of the stratigraphy associated with the known Flin Flon–Triple 7–Callinan VMS horizon, and has undertaken numerous drill programs and geochemical surveys to determine its extension farther west. Finally, D. Wyman (unpub. report, 1997) completed detailed high-resolution lithogeochemistry on volcanic strata in the Flin Flon area in order to further elucidate and extrapolate deposit stratigraphy.

The purpose of this subproject is to compile the data from these past studies, along with completion of detailed stratigraphic and structural studies, to design a new 1:10 000-scale geology map for the Flin Flon–Creighton region that will include all possible along-strike extensions of the Flin Flon–Triple 7–Callinan VMS deposit horizon. This will be the last component of the project to be completed in order to use all the new data that will become available from the Flin Flon Targeted Geoscience Initiative companion studies.

DETAILED SUBPROJECT STUDIES

Baker–Patton rhyolite complex alteration study (D. Mitchinson (M.Sc., Laurentian University) and G. Gale (MGS))

The Baker–Patton rhyolite complex is the most easterly VMS-hosting domain within the Flin Flon volcanic arc assemblage (Fig. 1), and taking into account folding and fault duplication, is the largest volume of felsic volcanic rock within this part of the Flin Flon greenstone belt. Due to several bounding regional faults and lack of U-Pb age dating, its relative stratigraphic position remains unknown. Despite its large volume, it is host to only a number of small past-producing mines (Pine Bay, Don Jon, and Northstar) and occurrences (Baker–Patton, Cabin Zone, and Leo Lake). At the request of companies working in the area, a complex-wide alteration study was undertaken in order to determine whether hydrothermal mineral vectors would assist in the further evaluation of the VMS potential of the area.

Both lithological and alteration maps have been produced by way of visual deduction. Samples were collected so as to represent relatively unaltered to strongly altered rhyolite bodies of the complex and various physical components of the rhyolite flows.

The sampling scheme was chosen in order to create a geochemical reference frame which could be used to help account for any changes that occur in geochemistry — specifically in the alteration mineralogy in order to complete a mineral alteration map of the entire complex based on X-ray diffraction (XRF) and mineral chemical data.

With regard to future work, alteration mineralogy will be determined using XRD and placed into context with individual rhyolite flows and with the location of various deposits which exist, or have existed, in the Baker–Patton complex.

Bear Lake alteration study (A. Galley (GSC) and A. Bailes (MGS))

The study of the Flin Flon volcanic assemblage by Bailes and Syme (1987) defined the fault-bounded Bear Lake structural domain as containing a large portion (4 km by 11 km) of a basalt flow-dominated volcanic edifice topped to the east by a cauldron complex which contains the Cuprus and White Lake VMS deposits (Fig. 1). As a result of their study, a large, epidote-rich alteration zone was identified affecting over 40% of the volcanic stratigraphy (Fig. 4, Fig 5A). This type of alteration commonly defines the higher temperature parts of sub-seafloor alteration systems, where it is in close spatial association with subvolcanic sills and feeder dyke swarms (Gibson and Watkinson, 1990; Galley, 1993; Galley and Koski, 1999, Santaguida, 1999). If the model is correct, the large area of epidote-rich alteration affecting the Bear Lake volcano would suggest much larger quantities of metals were mobilized than were sequestered within the known deposits of Cuprus and White Lake.

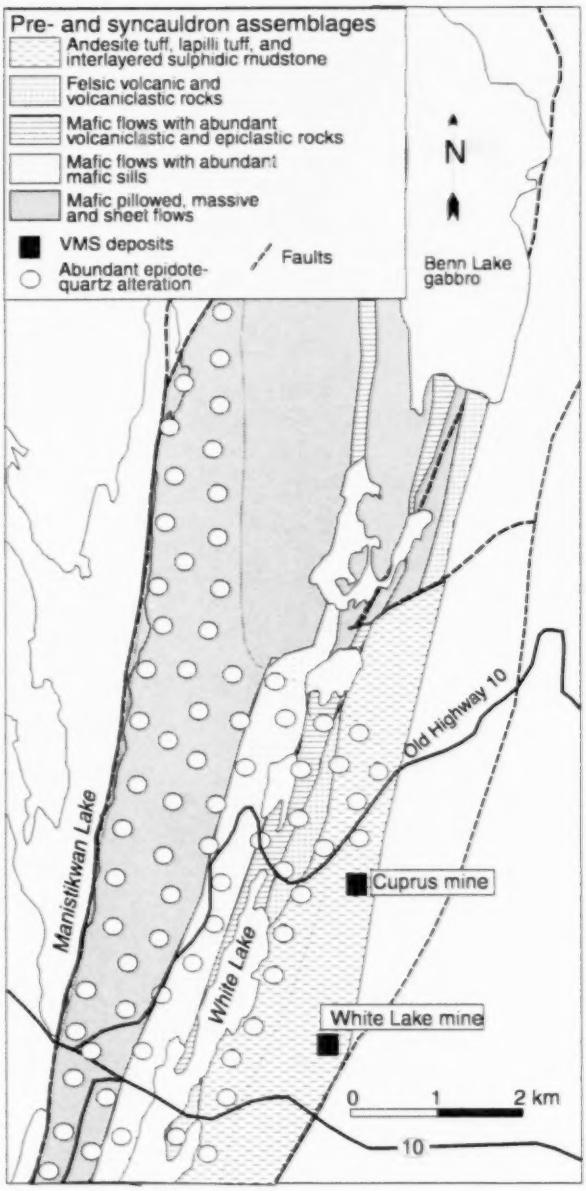

Figure 4. *Modified geology from Bailes and Syme (1987) of the pre- to syncauldron volcanic assemblages comprising the Bear Lake volcano. The white dots indicate areas of the volcano affected by moderate to strong quartz-epidote alteration believed to represent sub-seafloor, high-temperature seawater-rock interaction. The overlying Cuprus and White Lake VMS deposits are hosted by sulphidic argillic units within an andesitic tuff and lapilli tuff succession intruded by abundant mafic sills.*

The purpose of the project is to gain a better understanding of the Bear Lake alteration system through completion of surface cross-sections every 500–1000 m through the exposed volcanic stratigraphy in order to more closely document alteration morphologies and mineralogical variations, and their relationship to changes in volcanic flow facies and abundance of synvolcanic dykes and sills. This was done using the original quarter-mile airphotos from the Bailes and Syme (1987) study in order that optimal use can be made of the existing database and archived sample set.

During the 2001 field season ten traverses were completed and a total of 140 samples collected. The sampling included most- and least-altered volcanic examples from each outcrop, and samples of synvolcanic dykes and sills to demonstrate the various degrees of alteration that they have undergone. Empirical observations indicate noticeable variations in the epidote:quartz content of altered pillowed to massive flows, with the presence of a semiconformable zone of silicification near the top of the precauldron basalt succession (Fig. 5B). This is overlain by a thin, mafic, cobble breccia unit which is sulphide stained for much of its 2000 m strike length. Both the silicified basalt and overlying mafic cobble breccia is transected by a several hundred metre long discordant zone of pyrrhotite-pyrite-chalcopyrite dissemination and veins. The discordant zones of sulphide veining and vesicle infilling are unrelated to the known massive sulphide deposits.

The zone of most extensive epidote alteration defined by Bailes and Syme (1987) appears to contain several generations of gabbro-diorite dykes and sills. Initial observations suggest that syn- and postvolcanic intrusions can be

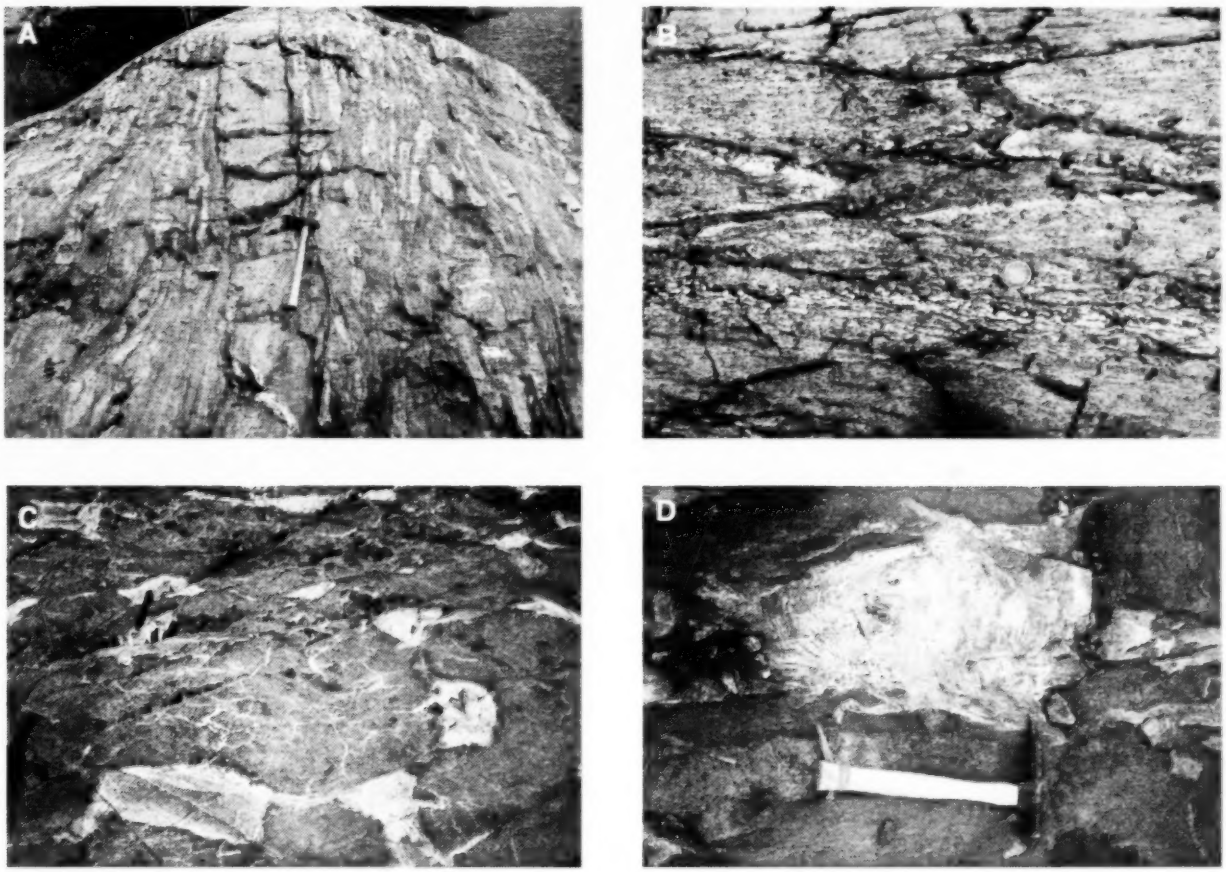

Figure 5. ***A)*** *An example of strongly quartz-epidote altered pillowed basaltic andesite flows in the precauldron part of the Bear Lake volcano cut by an epidote-altered, synvolcanic mafic dyke. These pillows have been strongly flattened during deformation. Hammer (40 cm long) for scale.* ***B)*** *Pillowed flow near the top of the precauldron basaltic andesite succession of the Bear Lake volcano affected by strong silicification accompanied by weak pyrrhotite-chalcopyrite mineralization. Two dollar coin (4 cm) for scale.* ***C)*** *Hidden Lake Formation basalt pillows partly surrounded by finely laminated mafic sediment. Photograph field is approximately 1.5 m across.* ***D)*** *Chert infilling between Hidden Lake formation pillows in the hanging wall to the Triple 7 VMS deposit. The chert is postulated to be a product of low-temperature leakage of a hydrothermal plume above the deposit. Hammer (40 cm long) for scale.*

differentiated by the presence of varying degrees of quartz-epidote-amphibole-magnetite-chlorite alteration in the synvolcanic intrusions. This indicates that the earlier gabbroic intrusions most likely interacted with the circulating seawater responsible for the broader epidote alteration zone. The distribution and volume of these earlier intrusions may have influenced the positioning and morphology of the epidote-rich alteration zone within the Bear Lake volcano.

Stratigraphy and structure of the Flin Flon mine area

1:500-scale mapping (A. Bailes (MGS), H. Gibson (Laurentian University), G. Tourigny (SGS), R. Syme (MGS), and Debbie Bray (B.Sc., University of Manitoba))

Effective delineation of the VMS-hosting stratigraphy at Flin Flon has been hampered in the past by the location of the mine stratigraphy astride the border between Manitoba and Saskatchewan, with the attendant division of responsibilities between two provincial geoscience agencies. Crossborder mapping at 1:500 scale was undertaken to resolve some long-standing controversies about the location and nature of the Flin Flon mine horizon. The 1:500-scale mapping program will continue into the 2002 field season and, probably beyond. In 2001 1:500-scale mapping projects were undertaken in areas around the South Main shaft by A. Bailes and R. Syme (MGS) which include detailed mapping and study of primary features in the South Main rhyolite complex by Debbie Bray (University of Manitoba) and on Millrock hill directly south of the South Main headframe (Fig. 2) by H. Gibson (Laurentian University), G. Tourigny (SGS), A. Bailes (MGS), and R. Syme (MGS).

South Main shaft mapping

Crossborder mapping at 1:500 scale was undertaken in the vicinity of Flin Flon South Main shaft (Bailes et al., 2001) to resolve some long-standing controversies about the location of the southern extension of the Flin Flon mine horizon. Mapping by Stockwell (1960) at 1:12 000 scale indicated that the ore-hosting rhyolite for the Flin Flon VMS deposit linked to the south with some large rhyolite complexes (north of South Main shaft) in a broad, curving, open Z-shaped structure and then with smaller rhyolite complexes further to the south at Millrock hill. Mapping at 1:20 000 scale by Bailes and Syme (1987) suggested that: 1) the mine horizon continues straight to the south and east of the South Main shaft area; 2) the rhyolite complex north of the South Main shaft consists of high-level intrusions still in the footwall stratigraphy to the mine; and 3) the mine horizon is structurally offset, perhaps by a dextral fault, to link up with rhyolite complexes at Millrock hill. Mapping at 1:10 000 scale by Thomas (1992) supported this finding, but proposed that offset of the mine-hosting rhyolite package was the product of folding and not a consequence of a fault.

The B.Sc. thesis study of the South Main rhyolite complex by Debbie Bray to determine whether primary features, geochemistry, and map distribution of the South Main rhyolite complex support an intrusive or extrusive origin, and whether this rhyolite complex is the extension of the 'Mine rhyolite' that hosts the Flin Flon VMS deposit. The objective of the 1:500-scale mapping by A. Bailes and E.C. Syme is to provide the broader geological context for the South Main rhyolite bodies and a more refined stratigraphy for the Flin Flon mine area. Both projects have contributed to provide a 1:500-scale map of the South Main shaft area (Bailes et al., 2001).

These projects have considerably refined our geological understanding of the South Main area and have brought to light the following critical pieces of information.

The South Main rhyolite is composed of three recognizable units which are part of a flow-dome complex. Although much of the rhyolite complex are clearly intrusive, there is considerable evidence that the complex is, at least in part, extrusive.

The South Main rhyolite is emplaced and/or extruded within a volcaniclastic package (previously unrecognized) that is composed of mafic wacke-siltstone, monolithological rhyolite breccia, and arenite containing detrital quartz and lithic felsic clasts. The South Main volcaniclastic package shares many characteristics with those enclosing rhyolite bodies at Millrock hill.

Basalts stratigraphically overlying the South Main rhyolite complex are broadly folded and appear to correlate with similar flows directly to the south across the trace of the fault proposed by Bailes and Syme (1987) and the fold proposed by Thomas (1992).

These observations raise some serious questions about the Flin Flon mine stratigraphy as proposed by Bailes and Syme (1987). Clearly, further 1:500-scale mapping and systematic geochemistry of both basalt and rhyolite flows in the immediate Flin Flon area are needed to resolve this important geological issue. A consequence of resolving the stratigraphy in the immediate area of the Flin Flon mine horizon will be the more effective identification of the mine-hosting package elsewhere and more cost-effective exploration of this sequence on the east side of the Hidden Lake syncline in Manitoba and the west side of the Flin Flon anticline in Saskatchewan.

Millrock hill mapping

The 1:500-scale mapping of Millrock hill (Gibson et al., 2001) builds upon previous 1:5000-scale mapping by D.P. Price (unpub. Hudson's Bay Exploration and Development Co. Ltd. map, 1992) and a detailed report by Syme (1998). The structural geology of the area is reported in a following section authored by G. Tourigny.

The predeformation Millrock hill geology comprises volcaniclastic rocks that are interpreted to have infilled a volcanic-tectonic depression on an underlying basalt sequence. The volcaniclastic rocks, which were accompanied by

extrusion of rhyolite complexes, had dual mafic and felsic sources. The basalt breccia and mafic components in these volcaniclastic rocks are interpreted to have been derived from an allogenic source (i.e. basalt basement from the margins of the depositional basin). The felsic components are interpreted to have been derived locally within the basin from the syndepositional rhyolite domes. Rapid thickness variations of some units in the depositional basin indicate that syndimentation subsidence occurred during infilling of this volcanic-tectonic depression. Determining the provenance and mechanism of deposition of the volcaniclastic rocks in the volcanic-tectonic depression could play an important role in guiding VMS exploration in the mine sequence at Flin Flon. A separate M.Sc. project by C. Devine, targeting this aspect of the volcaniclastic rocks, is described in a following section.

Structural observations on Millrock hill (G. Tourigny, SGS)

Structural observations are being collected concurrently with 1:500-scale mapping. The objective is to delineate structural events that have affected the mine-hosting stratigraphy. This report summarizes structural observations made in the Millrock hill area during the 2001 field season.

Planar and linear structural elements observed at Millrock hill result from the generation of D_1 and D_2 structures. The D_1 structures formed a weak subhorizontal S_1 foliation observed in the hinge zone of F_2 folds at a high angle to the dominant S_2 regional schistosity. At the outcrop scale, S_1 has no significant effect on the geometry of strata.

The D_2 deformation produced prominent folds (F_2) with associated axial-planar regional S_2 schistosity, L_2 lineations, and late D_2 fault zones. The structural pattern of the area is dominated by the presence of a major F_2 fold, which is obliquely truncated and dismembered by northwest-trending ductile faults (Gibson et al., 2001). This fold, a major synclinal flexure plunging at 35° toward the southeast, is largely responsible for the spatial distribution of rock types. The S_2 planes contain a strongly developed fragment and mineral stretching lineation (L_2) which plunges at a general angle of 35° toward the southeast and are essentially collinear with the F_2 fold axis.

A well developed network of anastomosing fault zones formed at a very low counter-clockwise angle to S_2 (Gibson et al., 2001). The fault zones contain chlorite-epidote-carbonate schist with local protomylonite with a steep east-dipping foliation and well developed extension lineations. The fault-zone foliation and lineations represent accentuated S_2 and L_2 fabrics. The relative attitudes of the internal foliation and the extension lineation within the fault zones indicate that these structural discontinuities are northwest-verging, late D_2 oblique-reverse faults with minor sinistral displacement.

A set of younger, north-northeast-trending brittle faults produced up to 18 m of right-lateral displacement of lithological contacts and earlier structures (Gibson et al., 2001). These dextral strike-slip faults are subvertical and less that 1 m wide.

The finite geometry and styles of major tectonic structures recognized in the Millrock hill area result from a northeast- to east-northeast-trending subhorizontal shortening and oblique, dip-slip elongation. The anastomosing character of the major D_2 fault system suggests a bulk inhomogeneous flattening type of deformation. The recognition of the structural style affecting these rocks to the south will result in a more definitive extrapolation of the Flin Flon mine horizon south of its present known strike length.

Flin Flon mine stratigraphy: volcaniclastic project (C. Devine (M.Sc., Laurentian University))

The volcaniclastic rocks that are found within the footwall to the main ore deposits in the Flin Flon mine stratigraphy have had limited detailed analysis. The main purpose of the study on the volcaniclastic package of rocks is to analyze the VMS-hosting rift basin in order to determine the mechanism of emplacement of the various breccia units, the provenance for the different clast types observed, and the depositional environment.

Four main areas were examined (Fig. 2). In each of these areas a detailed stratigraphic section (or sections) has been measured to demonstrate variations within and between depositional units. Clast counts and measurements with the aid of a 1 m grid involved measuring the three largest clasts of each type of clast within a square area. A detailed description of each unit included the sorting, matrix composition, and relationship to other depositional units while a detailed description of the clasts within a depositional unit included colour, shape, and size of clasts; and amygdale and phenocryst size and percentage and orientation. Trace-element geochemistry and petrography will be used in conjunction with the quantitative component of the clast counts to assess the composition of the various clast samples taken. The 1:500-scale mapping of two areas within the mine site will also aid in analyzing the breccia across basin as it shows a very detailed distribution of the various depositional units in the volcaniclastic package in a given area.

Stratigraphic and alteration studies of the Flin Flon VMS horizon hanging wall

Part 1: Flin Flon hanging-wall alteration study (D. Ames, GSC)

One of the most interesting and least known aspects of VMS metallogeny is the nature and extent of alteration halos within the hanging-wall stratigraphy to massive sulphide deposits. Hanging-wall alteration can be formed as a result of the continuation of hydrothermal activity after burial of lava flows or by the generation of argillaceous hydrothermal sediments, for example, by prolonged low-temperature exhalations in the waning stages of ore formation at depth. These concepts were reinforced by studies of the Horne (Kerr and Gibson, 1993), Kidd Creek (Hannington et al., 1999), and Ansil (Galley et al., 1996) VMS deposits, which demonstrated that at least some thickness of hanging-wall stratigraphy was present as the economic portions of these deposits were emplaced or

reworked. Hydrothermal fluid leakage has been documented 500 m upsection from the Ansil deposit (Galley et al., 1996). If the nature and extent of this hydrothermal leakage marked by the presence of interpillow and interflow chert can be quantified it may become an ideal exploration tool to vector towards potential VMS-hosting stratigraphic intervals. These processes may also lead to the development of stacked ore lenses (e.g. Amulet A and Upper A deposits, Noranda), therefore the potential exists within hanging-wall alteration haloes for future discoveries higher in the stratigraphy.

The Flin Flon hanging-wall study is based on detailed observations of volcanic flow-facies changes and alteration characteristics within the thick succession of massive to pillowed Hidden Lake basalt and basaltic andesite flows (Bailes and Syme, 1987). These basalt flows directly overlie the rhyolite and volcaniclastic host strata to the Flin Flon, Triple 7, and Callinan deposits (Fig. 2). One of the most interesting aspects of this basalt succession is the occurrence of abundant interpillow sediment composed of varying proportions of hydrothermal chert, hyaloclastite, and alteration minerals (Fig. 5C, D). These hydrothermal-hyaloclastite sediments form cohesive interflow units at several levels of the hanging-wall stratigraphy, with one of the thickest units marking the top of the Hidden Lake basalt between Louis and Phantom lakes (Fig. 2). The amount of sediment present in this formation, and its high degree of hydrothermal modification, suggest that they were an ideal permeable conduit for migrating hydrothermal fluids.

Six sections were completed across the Hidden Lake basalts from the north end of Phantom Lake to the Club Lake Fault, where the section is in fault contact with younger Missi Group sedimentary strata (Fig. 2). In addition to detailed section mapping at 1:2000 scale, occurrences of interflow and interpillow sediment were sampled (>200) to evaluate variations in mineralogy, mineral chemistry, and major- and trace-element chemistry.

Part 2: Triple 7 hanging-wall stratigraphy and alteration study (Nicole Tardif (M.Sc., Laurentian University))

Whereas the hanging-wall study by D. Ames is taking a regional scale approach to determining the presence of hydrothermal plumes above known and perhaps unknown deposits along the Flin Flon horizon, this study will focus on the immediate environment of the Triple 7 deposit to detect and document hanging-wall hydrothermal leakage. This entails 1:1000-scale surface mapping and sampling of the hanging-wall basalt stratigraphy to the Triple 7 VMS deposit from between its lower contact with the Railway volcaniclastic unit to the approximate position of the Hidden Lake, F_2 synform (Fig. 2). This area of approximately 300 m by 600 m directly overlies the up-plunge extensions of the two 'arms' of the Triple 7, plus the extension of the Callinan South massive sulphide lens. To date, four principal flow units have been defined, along with numerous dykes and sills of varying compositions and ages. Some flow facies are characterized by abundant interpillow hydrothermal sediment and altered pillow cores. Disseminated sulphide mineralization appears to be restricted to certain parts of the stratigraphy due to the distribution and correlated variability of primary permeability, and the possible damming effect of basalt feeder dykes.

Mapping has also led to the recognition of several low-angle, deformed faults which support the occurrence of an early thin-skinned fold-thrust event. This is of importance due to displacement and duplication of both volcanic stratigraphy and associated massive sulphide bodies. These results will be linked with the structural study presently being carried out underground by Hudson's Bay Mining and Smelting Co. Ltd.

After completion of the surface mapping and sampling, two drill holes were chosen for logging and sampling. These long holes were collared several hundred metres into the Hidden Lake basalt formation and intersected the Triple 7 sulphide mineralization. This allowed for detailed sampling for alteration to be completed directly above the economic portion of the mineralization. The approximately 200 samples collected are now being processed for petrographic and geochemical analysis, and the surface map digitized.

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